RESEARCH MEMORANDUM

COMPONENT PERFORMANCE INVESTIGATION OF J71 TYPE II TURBINES

III - OVER-ALL PERFORMANCE OF J71 TYPE IIA TURBINE

By Harold J. Schum, Elmer H. Davison, and Donald A. Petrash

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

The over-all component performance characteristics of the J71 Type IIA three-stage turbine were experimentally determined over a range of speed and over-all turbine total-pressure ratio at inlet-air conditions of 35 inches of mercury absolute and 700° R. The results are compared with those obtained for the J71 Type IIF turbine, which was previously investigated, the two turbines being designed for the same engine application. Geometrically the two turbines were much alike, having the same variation of annular flow area and the same number of blades for corresponding stator and rotor rows. However, the blade throat areas downstream of the first stator of the IIA turbine were smaller than those of the IIF; and the IIA blade profiles were curve-backed, whereas those of the IIF were straight-backed.

The IIA turbine passed the equivalent design weight flow and had a brake internal efficiency of 0.880 at design equivalent speed and work output. A maximum efficiency of 0.896 occurred at 130 percent of design equivalent speed and a pressure ratio of 4.0. The turbine had a wide range of efficient operation. The IIA turbine had slightly higher efficiencies than the IIF turbine at comparable operating conditions. The fact that the IIA turbine obtained the design equivalent weight flow at the design equivalent operating point was probably a result of the decrease in the blading throat areas downstream of the first stator from those of the IIF turbine, which passed 105 percent of design weight flow at the corresponding operating point. The third stator row of blades of the IIA turbine choked at the design equivalent speed and at an over-all pressure ratio of 4.2; the third rotor choked at a pressure ratio of approximately 4.9.

INTRODUCTION

The NACA Lewis laboratory is currently investigating three-stage Type II experimental turbines for the J71 turbojet engine. This research

is part of a general study of high-work-output low-speed multistage turbines. Two different turbines were evolved for the same engine application, the Type IIF and the Type IIA. Both turbines are of conservative aerodynamic design with respect to Mach number, turning in a blade row, and work output per stage. Both incorporate fully shrouded first- and second-stage rotors and unshrouded third-stage rotors. The two turbines have the same number of blades in each corresponding blade row, and the annular-area variation through both turbines is the same. The two designs differ in blade profile shapes and blade throat areas. The blade profiles in the IIF turbine are straight-backed, whereas the IIA turbine employs curve-backed blades. The design throat area for each row of blades in the IIF turbine was greater than the corresponding area of the IIA turbine as a result of different design assumptions.

Subsequent to the design of the IIF turbine, a further analysis by the engine manufacturer indicated that the throat areas through the stators were too large. Accordingly, the turbine was fabricated with stators having 97-percent of their design throat areas. This turbine was then investigated at inlet conditions of 35 inches of mercury absolute and 700° R, and the over-all performance characteristics are reported in reference 1. At equivalent design speed and work, the turbine had a brake internal efficiency of 0.877. However, the turbine equivalent weight flow at this operating condition was 5 percent greater than the design value, even though the stator flow areas had been decreased to 97 percent of their original design value. The IIF turbine had a maximum efficiency of 0.886 at a pressure ratio of 4.0 and 120 percent of equivalent design speed. In general, the IIF turbine had a wide range of efficient operation.

In addition to the over-all performance, a detailed study of the internal flow conditions of this IIF turbine was conducted at the equivalent design operating point (ref. 2). Design stage work was obtained with local indicated stage efficiencies of 0.894, 0.858, and 0.792 for the first, second, and third stages, respectively. Contributing factors to the low efficiency of the third stage may have been the relatively large blade tip clearance (0.100 in.) and the fact that this rotor was unshrouded.

The subject report presents the over-all performance of the Type IIA turbine and compares the results with those for the Type IIF turbine (ref. 1) in order to determine the effect of decreased blade throat areas downstream of the first stator and curve-backed blades on over-all turbine performance. Reference 3 indicates that, within the range of Mach numbers encountered in the Type II turbine designs, the blade curvatures downstream of the throat sections of the IIA turbine blading would result in no increase in blade profile losses over the straight-backed blading of the IIF turbine. The effect of the blading throat-area variations of the two turbines on turbine performance, however, is difficult to predict. Consequently, in order to ascertain the effect of these two geometric variables on turbine performance, the IIA turbine was experimentally investigated at inlet conditions of 35 inches of mercury absolute and 700° R,

over a range from 20 to 130 percent of equivalent design speed and of rating total-pressure ratio from 1.4 to 4.8. Turbine over-all performance is presented in terms of brake internal efficiency and equivalent work (both based on torque measurements), equivalent rating total-pressure ratio, equivalent rotational speed, and equivalent weight flow. Measurements of interstage static pressure are also presented. Additional data are included in table I.

SYMBOLS

The following symbols are used in this report:

E	enthalpy drop based on torque measurements, Btu/lb
g	acceleration due to gravity, 32.174 ft/sec^2
N	rotational speed, rpm
p	pressure, in. Hg abs
p_x'	rating total pressure, static pressure plus velocity pressure corresponding to axial component of velocity, in. Hg abs
R	universal gas constant, 53.4 ft-lb/(lb)($^{\circ}$R)
T	temperature, $^{\circ}$R
w	weight flow, lb/sec
$\frac{wN}{60\delta}\varepsilon$	weight-flow parameter based on product of equivalent weight flow and equivalent speed
γ	ratio of specific heats
δ	ratio of inlet-air pressure to NACA standard sea-level pressure, $p_0'/29.92$
ε	function of γ, $\frac{\gamma_{sl}}{\gamma_e}\left[\frac{\left(\frac{\gamma_e+1}{2}\right)^{\frac{\gamma_e}{\gamma_e-1}}}{\left(\frac{\gamma_{sl}+1}{2}\right)^{\frac{\gamma_{sl}}{\gamma_{sl}-1}}}\right]$

η_i brake internal efficiency, ratio of actual turbine work based on torque measurements to ideal turbine work based on inlet total pressure p_0' and outlet rating total pressure $p_{x,7}'$

θ_{cr} squared ratio of critical velocity to critical velocity at NACA standard sea-level temperature of 518.7° R,

$$\frac{\frac{2\gamma}{\gamma + 1} gRT_0'}{\frac{2\gamma_{sl}}{\gamma_{sl} + 1} gRT_{sl}}$$

τ torque, ft-lb

Subscripts:

e engine operating conditions

sl NACA standard sea-level conditions

x axial

0,1,2,3,
4,5,6,7, measuring stations (see fig. 2)
8

Superscripts:

' total or stagnation state

APPARATUS, INSTRUMENTATION, AND PROCEDURE

The three-stage J71 Type IIA turbine test installation used in this investigation is the same as described in reference 1 for testing the Type IIF turbine. As mentioned previously, the Type IIA turbine employed curve-backed blades and had smaller blade throat areas downstream of the first stator than did the Type IIF turbine (ref. 1). The design throat areas for the IIA turbine were 94.7, 92.5, and 92.3 percent of those of the IIF turbine for the first, second, and third stators, respectively, and 94.9, 95.0, and 92.6 perçent for the first, second, and third rotors, respectively. The actual measured stator throat areas for the IIA turbine are 100.5, 95.4, and 92.3 percent of those for the IIF turbine for the first, second, and third stators, respectively. The measured variations between the corresponding stator throat areas for the IIA turbine and the IIF turbine of reference 1 are different from the design variations, because (1) the stator areas of the IIF turbine as investigated were intended to be 97 percent of the design area, whereas the stator areas of the IIA turbine are 100 percent of design, and (2) these intended differences were further altered because of manufacturing tolerance

limits. The result was the measured variations listed. It should be noted, however, that the IIA turbine had smaller measured blade throat areas downstream of the first stator than the IIF turbine.

The sea-level design conditions, as supplied by the engine manufacturer, and the turbine design equivalent conditions are as follows:

	Engine sea-level design conditions, zero ram	Turbine equivalent design conditions
Work, Btu/lb	131.5	32.4
Weight flow, lb/sec	169.0	40.3
Rotational speed, rpm	6100	3028
Inlet temperature, $^{\circ}R$	2160	518.7
Inlet pressure, in. Hg abs	261.5	29.92

The method of deriving these equivalent design conditions is presented in reference 4. The IIA turbine was designed so that the first stage would produce 42 percent of the total work, the second stage 34 percent, and the third stage 24 percent. A photograph of the over-all turbine experimental setup, showing the various components, is shown in figure 1.

The instrumentation used in this investigation was the same as described in reference 1; a schematic diagram of the turbine, showing the instrumentation, is presented in figure 2. Measurements of total pressure, static pressure, and total temperature were taken at the turbine inlet (station 0) and at the turbine outlet (station 7). In addition, static-pressure taps were installed on the inner and outer shrouds ahead of each row of blades.

The IIA turbine was operated at constant nominal inlet pressure p_0' and temperature T_0' corresponding to 35 inches of mercury absolute and 700° R. Nominal pressure ratios were imposed across the turbine, and the speed was varied from 20 to 130 percent of the design equivalent speed $N/\sqrt{\theta_{cr}}$ for each pressure ratio. A range of rating pressure ratios from 1.4 to 4.8 was investigated.

Values of equivalent torque $(\tau/\delta)\varepsilon$ and equivalent weight flow $(w\sqrt{\theta_{cr}}/\delta)\varepsilon$ were plotted against the rating over-all total-pressure ratio $p_0'/p_{x,7}'$, and curves were faired for each speed investigated in order to minimize random experimental inaccuracies. The equivalent weight flows presented are corrected for the fuel addition required to maintain the 700° R inlet temperature. The turbine-outlet pressure $p_{x,7}'$, upon which the turbine efficiency is based, is calculated from the measured

total pressure, static pressure, total temperature, turbine weight flow (air flow plus fuel flow), and the known annular area at this measuring station. Efficiency based on this calculated outlet pressure charges the turbine for the energy of the rotor-discharge tangential velocity. Therefore, the values of brake internal efficiency η_i presented are conservative.

RESULTS AND DISCUSSION

The over-all performance of the J71 Type IIA turbine is presented in figure 3. The variation of equivalent shaft work E/θ_{cr} with the equivalent weight-flow parameter $(wN/60\delta)\varepsilon$ for lines of constant equivalent rotational speed $N/\sqrt{\theta_{cr}}$ and rating total-pressure ratio $p_0'/p_{x,7}'$ is shown. Contours of constant values of brake internal efficiency η_i are also included. All parameters are corrected to NACA standard sea-level conditions (29.92 in. Hg abs and 518.7° R). The design operating point is shown at the design equivalent speed and shaft work output (32.4 Btu/lb). This design operating point occurred at an over-all total-pressure ratio of 3.42 and an efficiency of 0.880. Values of efficiency greater than 0.89 were obtained at equivalent speeds and work outputs greater than design. The maximum efficiency of 0.896 occurred at 130 percent of design equivalent speed and a pressure ratio of 4.0. It is apparent from the performance map that a broad range of efficient turbine operation exists. Comparison of this map (fig. 3) with that for the Type IIF turbine (fig. 3, ref. 1) reveals that the two turbines had comparable efficiency characteristics, the IIA turbine exhibiting slightly higher values. It will be noted, however, that the IIA turbine handled less equivalent weight flow than the IIF turbine at any given turbine speed.

The efficiencies of the IIA and IIF turbines can be compared more readily by referring to figure 4, where these efficiencies are presented as a function of the over-all total-pressure ratio for speeds of 70, 100, and 130 percent of design equivalent speed. The Type IIA turbine presented a slightly higher efficiency (approximately 1 percent) for the two higher speeds (figs. 4(b) and (c)). At the design equivalent speed (fig. 4(b)) and near the pressure ratio at which design equivalent work was obtained for the two turbines (approximately 3.4), the IIA turbine efficiency was on the order of 0.3 percent greater than that for the IIF turbine. The change in the blade throat areas and profile shapes therefore resulted in only a slight increase in turbine efficiency.

The variation of equivalent weight flow $(w\sqrt{\theta_{cr}}/\delta)\varepsilon$ with over-all rating total-pressure ratio for the IIA turbine is presented in figure 5 for all equivalent rotational speeds investigated. The figure indicates that the turbine is choked above a pressure ratio of 4.0 for speeds

above 70 percent. In this speed range, the choking value of weight flow (maximum weight flow for a given speed) decreases with an increase in rotational speed. This indicates that, for the rotational speeds above 70 percent, the turbine chokes somewhere downstream of the first stator.

At the design operating point of 100-percent equivalent design speed and a work output of 32.4 Btu per pound, which corresponds to an over-all total-pressure ratio of 3.42, an equivalent weight flow of 40.4 pounds per second is indicated in figure 5. This compares very closely with the design value of 40.3 pounds per second. At the corresponding design operating point for the IIF turbine (ref. 1), 105 percent of design equivalent weight flow was observed. The reduction in blade throat areas downstream of the first stator of the IIA turbine from those of the IIF turbine was probably the reason the IIA turbine obtained the design weight flow at the equivalent design operating point.

The variation of equivalent torque $(\tau/\delta)\varepsilon$ with rating over-all total-pressure ratio for the various rotational speeds is shown in figure 6. Over the range of conditions investigated, equivalent torque continually increased with pressure ratio at all speeds. This indicates that turbine blade limiting loading was not encountered in this investigation. However, at the higher speeds and higher pressure ratios, the slope of these torque curves continually decreases, indicating that a blade limiting-loading condition is closely approached.

The variation of the static pressure p at the different hub measuring stations with rating over-all total-pressure ratio $p_0'/p_{x,7}'$ at the design equivalent rotor speed is presented in figure 7. All static pressures were divided by the inlet total pressure p_0' in order to eliminate experimental variations in the inlet total pressure. This curve is presented in order to determine which blade rows, if any, are choked. Blade-row choking is indicated from a plot such as figure 7 if the static pressure at the entrance to the blade row (i.e., ratio of the static pressure to turbine-inlet total pressure) remains constant while the static pressure at the exit of the same blade row decreases as the over-all total-pressure ratio across the turbine is increased. When a blade row does choke, the static pressures at all stations upstream of this blade row remain constant as the over-all total-pressure ratio across the turbine is increased.

From the foregoing discussion it may appear from figure 7 that the first stator is choked over most of the range of over-all total-pressure ratio investigated. However, in the range of over-all pressure ratios from 1.4 to 4.2, small differences in the static pressure at measuring station 1 persist, but are somewhat difficult to note readily because of the small scale of the ordinate. Actually, the first stator is unchoked

over the entire range of pressure ratio, because the static- to total-pressure ratio at the exit of the first stator (measuring station 2), which in this instance is representative of the Mach number at that measuring station, is far from the choking value of 0.528.

A blade-row choking phenomenon is indicated in figure 7 across the third row of stator blades, because the static-pressure curve at measuring station 5 obtains a zero slope at and above an over-all rating total-pressure ratio of approximately 4.2, while the static-pressure curve at measuring station 6 did not. Thus, the third stator row of blades is operating in a choked condition above an over-all total-pressure ratio of about 4.2. It should be noted that this pressure ratio is well above the pressure ratio at which the equivalent design turbine work was obtained (3.42). It would also appear from the static-pressure distributions at measuring stations 6 and 7 (fig. 7) that the third rotor row of blades begins to choke at an over-all total-pressure ratio of about 4.8 or 4.9. In the IIF turbine investigation (ref. 1), the third rotor choked at a pressure ratio of 4.2. Changes in the turbine geometry, then, resulted in a shift in the initial choke point from the third rotor for the IIF turbine to the third stator for the IIA turbine.

Because the third stator of the IIA turbine choked at an over-all total-pressure ratio of approximately 4.2, all curves for the preceding measuring stations have a zero slope at and above this choking pressure ratio (see fig. 7). It would also be possible for the static-pressure curves preceding measuring station 5 to obtain a zero slope simultaneously with the curve at measuring station 5 if one or more of the blade rows preceding the third stator choked simultaneously with the third stator. While this is possible, it is not considered likely that any preceding blade row chokes with the turbine design features such as they are. It is concluded that, at the design equivalent speed, the third stator of the IIA turbine choked at an over-all total-pressure ratio of 4.2; the third rotor choked at a pressure ratio of about 4.9; the first stator was unchoked over the entire pressure-ratio range investigated; and it is possible, but unlikely, that other blade rows were choked.

SUMMARY OF RESULTS

From an experimental investigation of the J71 Type IIA three-stage turbine equipped with design stator areas and operated over a range of equivalent speed and total-pressure ratio at inlet conditions of 35 inches of mercury absolute and 700° R, the following results were obtained:

1. At equivalent design speed and work, the turbine passed the equivalent design weight flow and had a brake internal efficiency of 0.880.

2. The turbine had a wide range of efficient operation, a maximum value of 0.896 occurring at 130 percent of design equivalent speed and a total-pressure ratio of 4.0.

3. At design equivalent speed the third stator choked at an over-all pressure ratio of 4.2. Subsequently, the third rotor choked at an over-all pressure ratio of about 4.9.

4. A comparison of the over-all performance of the IIA and IIF turbines at design equivalent speed and work indicated that the use of curve-backed blades and the reduction of the blade throat areas downstream of the first stator in the IIA turbine resulted in a slight increase in efficiency and a 5-percent decrease in weight flow.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, January 20, 1955

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TABLE I. - DATA SUMMARY FROM EXPERIMENTAL INVESTIGATION

OF J71 TYPE IIA TURBINE

Rating over-all total-pressure ratio, $p_0'/p_{x,7}'$	Over-all total-pressure ratio, p_0'/p_7'	Inlet total pressure, p_0', in. Hg abs	Inlet total temperature, T_0', ^oR	Outlet total temperature, T_7', ^oR	Turbine speed, N, rpm	Turbine weight flow, w, lb/sec	Torque, τ, ft-lb
1.366	1.3569	34.98	701.0	670.7	740	34.10	2504
1.373	1.3707	35.24	701.0	656.5	1412	33.41	1914
1.380	1.3686	34.94	700.9	651.2	2106	31.99	1367
1.369	1.3546	35.11	700.8	652.2	2460	31.38	1114
1.368	1.3444	34.86	700.7	653.8	2812	30.95	926
1.376	1.3485	35.17	700.8	658.4	3168	30.88	744
1.372	1.3309	34.87	699.8	663.3	3515	30.49	568
1.527	1.5045	35.13	701.1	666.1	707	37.19	3347
1.537	1.5299	35.02	701.1	645.2	1403	36.65	2687
1.537	1.5344	35.03	701.0	635.1	2112	35.51	2025
1.546	1.5367	34.93	701.0	633.2	2459	34.95	1765
1.539	1.5194	34.93	701.0	633.9	2806	34.32	1473
1.547	1.5155	35.10	701.0	635.1	3165	34.09	1252
1.564	1.5250	35.06	701.0	637.7	3513	34.10	1092
1.568	1.5195	35.04	701.0	642.4	3873	34.10	921
1.577	1.5174	35.13	701.0	646.1	4218	34.13	750
1.587	1.5167	35.02	701.0	653.3	4576	34.10	596
1.744	1.697	35.11	701.3	658.1	701	39.34	4144
1.767	1.753	34.96	701.3	631.5	1417	38.85	3449
1.797	1.806	34.95	702.3	617.2	2108	38.39	2808
1.807	1.806	34.96	702.5	611.2	2471	38.02	2549
1.823	1.812	34.96	702.2	608.4	2812	37.56	2240
1.771	1.762	35.04	702.1	610.9	3167	36.91	1865
1.788	1.746	34.98	702.1	613.3	3514	36.35	1627
1.781	1.727	35.09	702.1	616.5	3869	36.32	1396
1.815	1.746	34.98	702.1	618.7	4219	36.22	1258
1.798	1.714	35.08	702.1	626.5	4578	36.18	1032
1.938	1.870	35.10	701.3	654.1	710	40.28	4757
1.975	1.948	35.02	701.3	622.9	1410	40.08	4024
2.006	1.994	34.89	701.3	603.1	2104	39.59	3361
2.034	2.027	34.98	701.3	596.5	2462	39.34	3047
2.039	2.027	34.92	701.3	592.1	2812	38.92	2743
2.093	2.068	35.05	701.3	587.3	3159	38.69	2511
2.114	2.082	35.20	701.2	586.4	3516	38.59	2268
2.119	2.070	35.04	701.3	587.6	3868	38.16	2003
2.108	2.038	35.00	701.2	590.8	4219	37.88	1749
2.106	2.019	35.15	701.1	597.0	4578	37.90	1507
2.174	2.128	35.02	701.3	615.8	1402	40.84	4488
2.208	2.188	34.99	701.3	593.0	2108	40.54	3798
2.232	2.223	34.95	701.3	585.3	2458	40.06	3444
2.255	2.237	34.99	701.3	580.3	2815	39.88	3124
2.274	2.265	35.06	701.3	576.3	3174	39.46	2815
2.273	2.237	35.05	701.3	575.0	3527	39.04	2517
2.261	2.209	35.03	701.1	575.2	3872	38.76	2247
2.263	2.190	35.07	701.2	578.3	4216	38.58	1981
2.329	2.220	35.10	701.3	577.2	4567	38.58	1833
2.561	2.432	35.09	701.4	603.4	1404	41.39	5117
2.602	2.606	35.00	701.4	577.1	2117	41.19	4389
2.630	2.599	34.98	701.3	566.9	2464	41.18	4046
2.643	2.630	34.92	701.3	559.7	2810	40.53	3699
2.660	2.630	35.11	701.3	555.3	3164	40.43	3384
2.658	2.658	34.93	701.3	554.0	3515	39.87	3042
2.689	2.653	35.04	701.3	552.3	3876	39.69	2765
2.663	2.600	34.94	701.3	553.0	4221	39.27	2462
2.644	2.564	34.90	701.3	556.2	4568	39.09	2203

TABLE I. - Concluded. DATA SUMMARY FROM EXPERIMENTAL INVESTIGATION OF J71 TYPE IIA TURBINE

Rating over-all total-pressure ratio, $p_0'/p_{x,7}'$	Over-all total pressure ratio, p_0'/p_7'	Inlet total pressure, p_0', in. Hg abs	Inlet total temperature, T_0', °R	Outlet total temperature, T_7', °R	Turbine speed, N, rpm	Turbine weight flow, w, lb/sec	Torque, τ, ft-lb
2.859	2.692	34.91	701.5	597.5	1398	41.86	5514
2.965	2.875	34.96	701.5	565.3	2108	41.54	4821
2.997	2.942	35.01	701.4	554.5	2463	41.61	4480
3.049	2.991	35.15	701.4	545.4	2810	41.53	4183
3.040	3.045	35.23	701.5	539.9	3168	41.27	3803
3.039	3.023	35.01	701.3	537.1	3513	40.88	3463
3.009	3.007	35.09	701.3	535.9	3871	40.43	3100
3.034	2.992	35.16	701.4	534.6	4226	40.27	2841
2.994	2.926	35.03	701.3	536.8	4575	40.19	2539
3.275	3.157	35.30	701.5	557.3	2113	42.08	5124
3.264	3.166	35.05	701.4	545.5	2461	41.84	4755
3.281	3.281	34.91	701.3	537.4	2816	41.70	4387
3.303	3.230	35.01	701.3	529.8	3168	41.49	4021
3.313	3.354	35.02	701.4	526.5	3514	41.13	3727
3.363	3.353	35.04	701.3	520.8	3869	40.66	3389
3.350	3.344	35.04	701.3	521.3	4225	40.62	3083
3.358	3.316	35.12	701.3	520.5	4570	40.50	2852
3.432	3.386	35.04	702.4	522.6	3512	40.57	3781
3.429	3.392	35.04	703.3	525.4	3512	40.52	3753
3.400	3.352	34.99	702.3	525.1	3514	40.50	3753
3.404	3.352	35.03	702.3	522.4	3515	40.61	3743
3.559	3.320	35.13	701.3	549.7	2113	42.16	5327
3.608	3.442	35.11	701.5	537.7	2456	41.49	4969
3.604	3.525	35.07	701.5	528.3	2811	41.63	4656
3.562	3.453	35.05	701.5	523.2	3164	40.96	4177
3.756	3.658	35.08	700.3	510.3	3505	40.86	3992
3.595	3.540	35.05	701.0	517.4	3514	41.05	3886
3.687	3.645	35.14	701.3	512.4	3869	40.92	3622
3.651	3.632	35.12	701.3	512.7	4220	40.56	3314
3.672	3.630	35.14	701.3	509.3	4568	40.30	3017
4.010	3.651	35.01	701.4	528.4	2465	41.92	5217
3.947	3.613	35.01	701.4	522.7	2817	41.58	4772
3.977	3.797	35.16	701.4	513.0	3166	41.46	4474
4.142	3.813	35.04	700.3	502.5	3519	40.88	4190
4.007	3.883	35.14	701.4	507.7	3517	41.21	4139
3.930	3.844	35.13	700.4	509.0	3523	40.90	4069
4.061	4.118	35.13	701.3	502.0	3865	40.90	3842
3.956	3.956	35.05	701.3	503.5	4224	40.34	3452
3.963	3.880	35.11	701.3	500.8	4574	40.38	3210
4.485	3.913	34.98	701.5	521.9	2465	41.97	5420
4.238	3.867	34.92	701.4	514.5	2818	41.40	4975
4.514	4.236	35.03	701.5	504.9	3163	41.33	4705
4.599	4.268	35.00	700.3	495.0	3520	40.82	4416
4.332	4.098	35.00	700.3	498.5	3520	40.90	4312
4.458	4.234	35.31	701.5	499.0	3516	41.05	4304
4.473	4.548	35.25	701.3	495.2	3870	40.87	3990
4.536	5.040	34.93	701.4	490.6	4205	40.13	3721
4.608	5.258	35.02	701.3	488.1	4575	40.08	3446
4.628	4.050	34.99	701.4	509.8	2810	41.70	5099
4.815	4.364	34.91	701.5	499.6	3174	41.06	4751
4.942	4.564	35.19	701.4	494.1	3515	40.91	4476
4.822	4.454	34.96	700.4	493.4	3518	40.74	4472
5.001	4.633	35.21	701.4	489.5	3870	40.84	4146
5.118	4.852	35.52	701.3	486.9	4228	40.85	3888
5.217	4.997	35.53	701.4	485.0	4578	40.80	3613

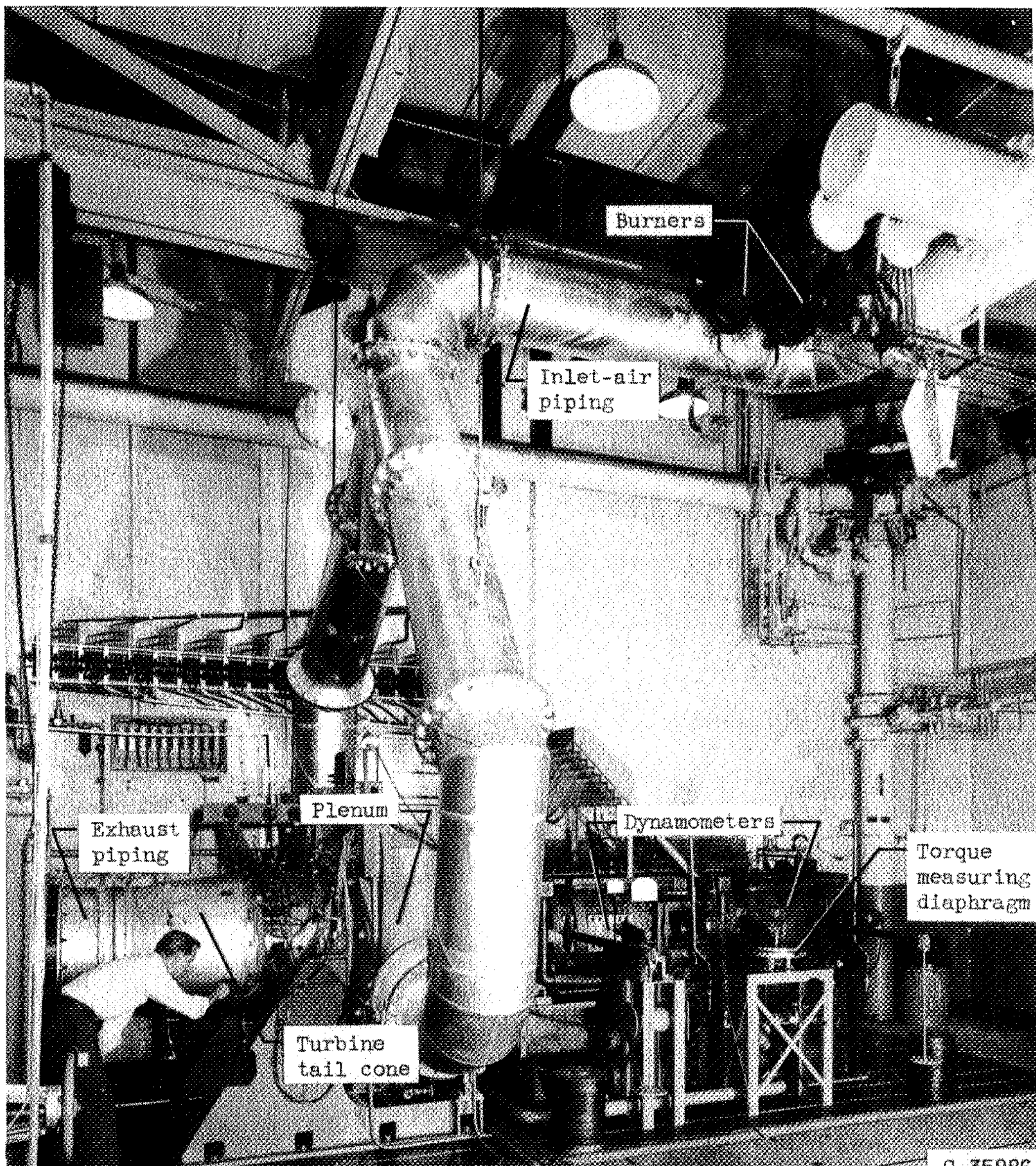


Figure 1. - Installation of J71 Type IIA three-stage turbine on full-scale turbine component test facility.

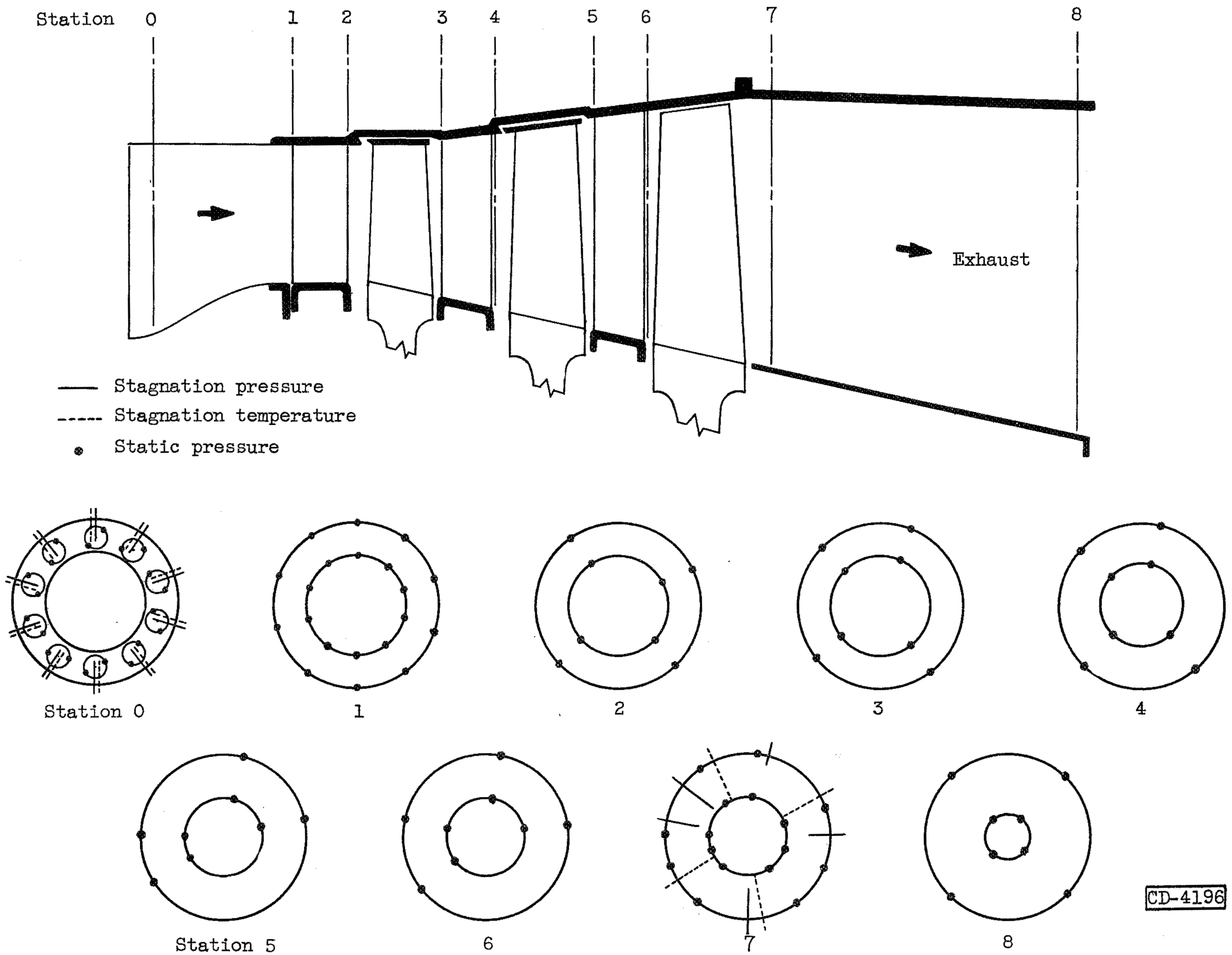


Figure 2. - Schematic diagram of J71 Type IIA turbine showing instrumentation.

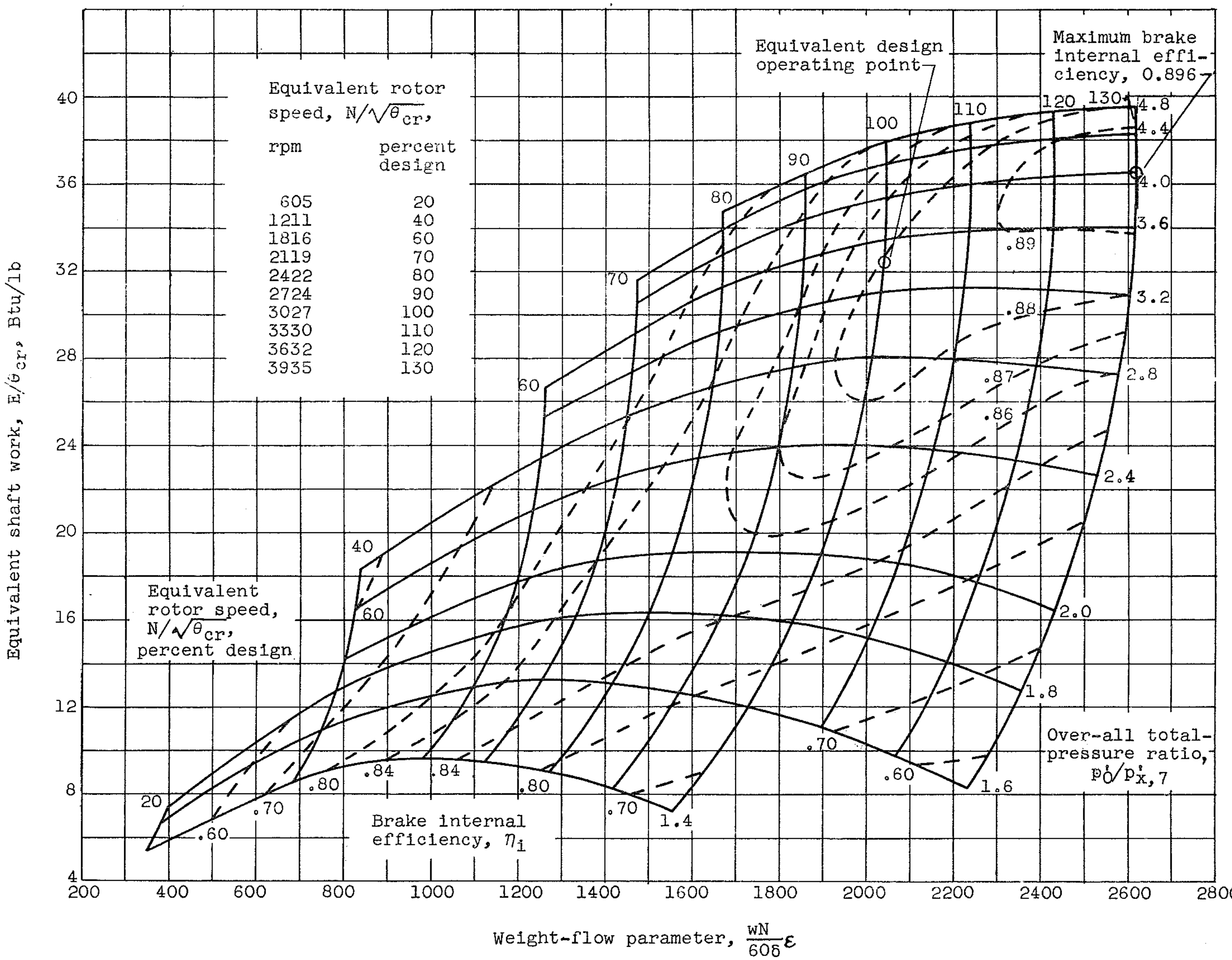
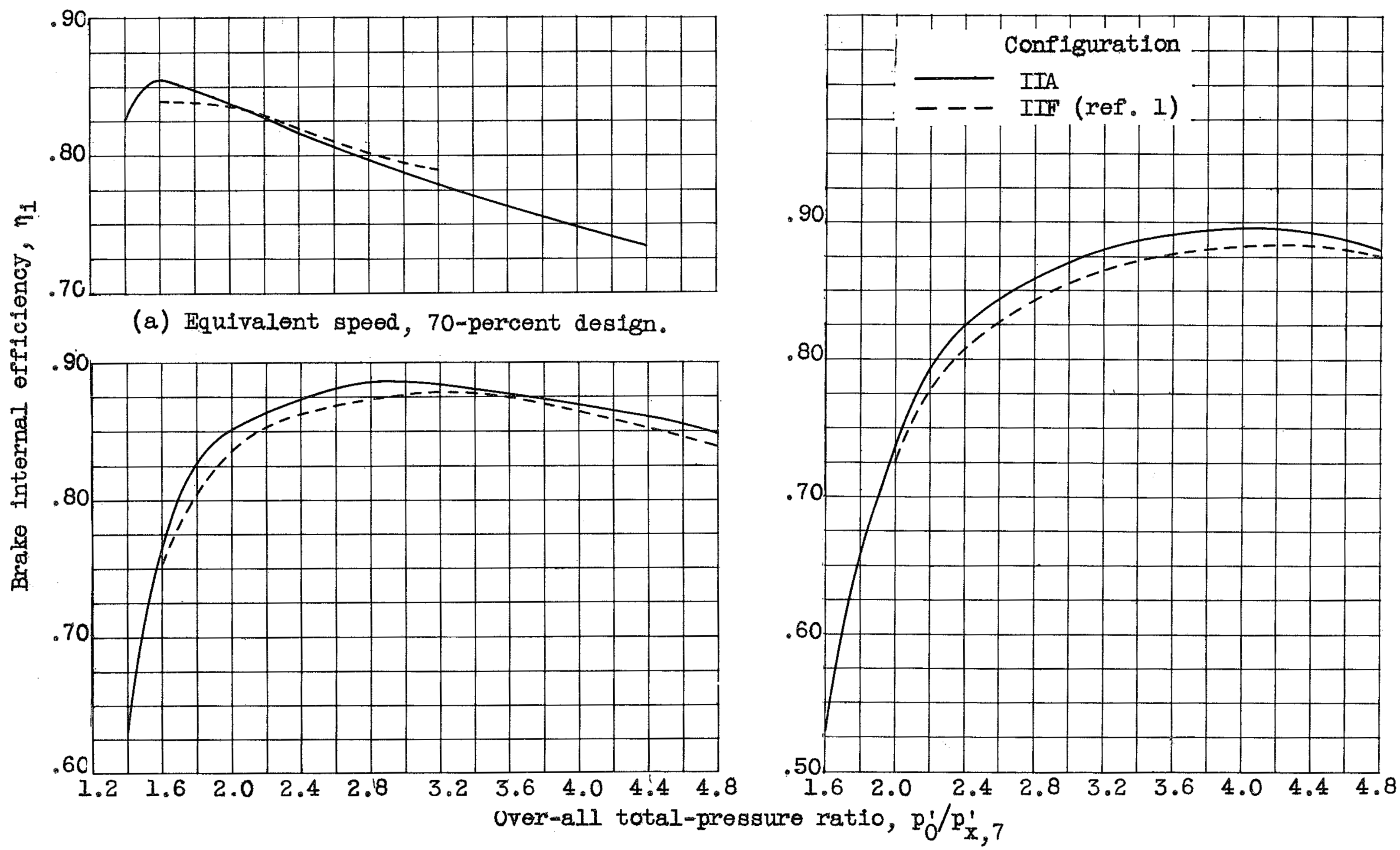


Figure 3. - Over-all performance of J71 Type IIA three-stage turbine. Turbine-inlet pressure, 35 inches of mercury absolute; turbine-inlet temperature, 700° R.



(a) Equivalent speed, 70-percent design.

(b) Equivalent speed, 100-percent design.

(c) Equivalent speed, 130-percent design.

Figure 4. - Variation of over-all turbine brake internal efficiency with over-all total-pressure ratio at three different rotational speeds for two J71 turbine configurations.

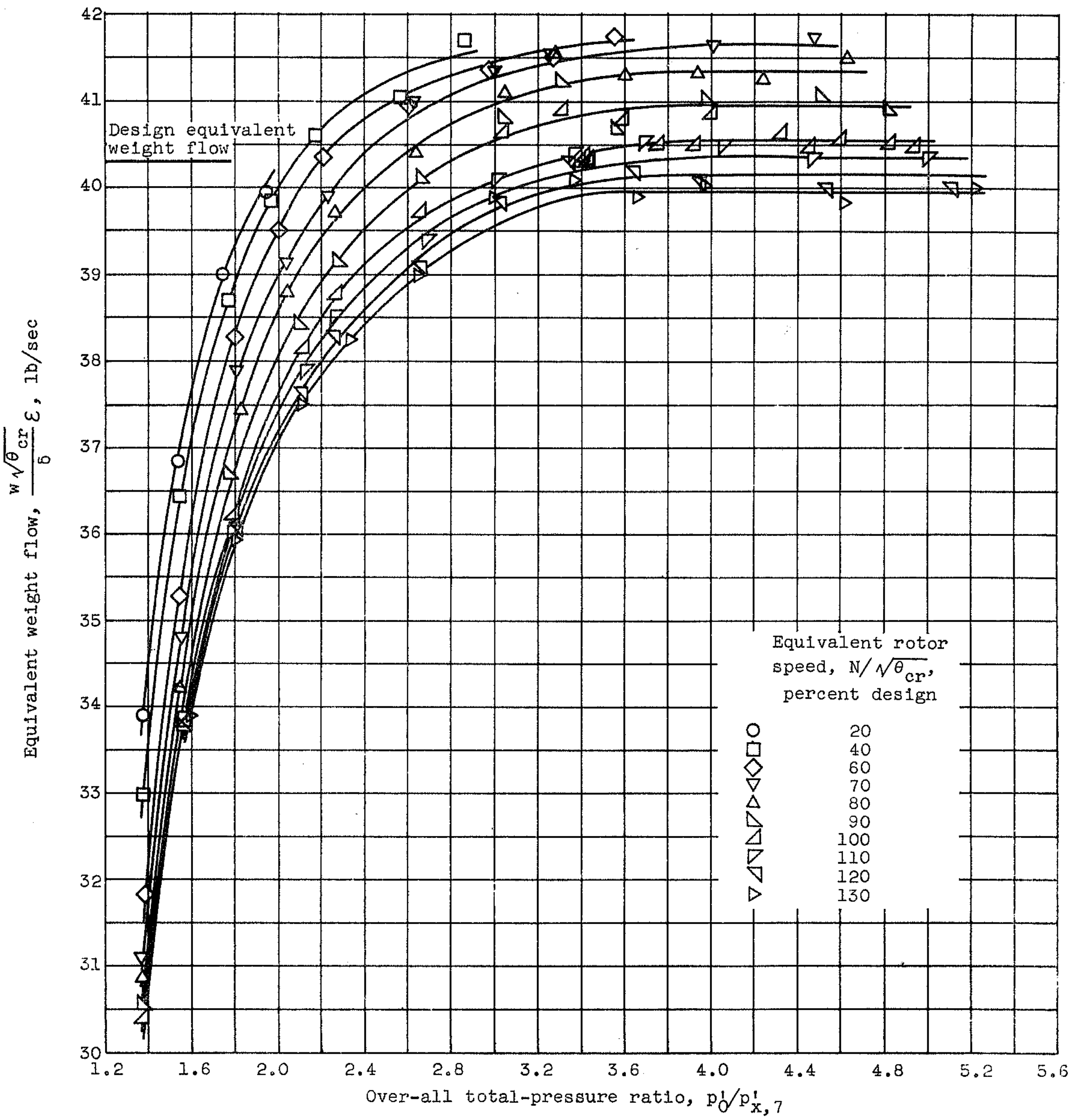


Figure 5. - Variation of equivalent weight flow with over-all total-pressure ratio for values of constant equivalent rotor speed.

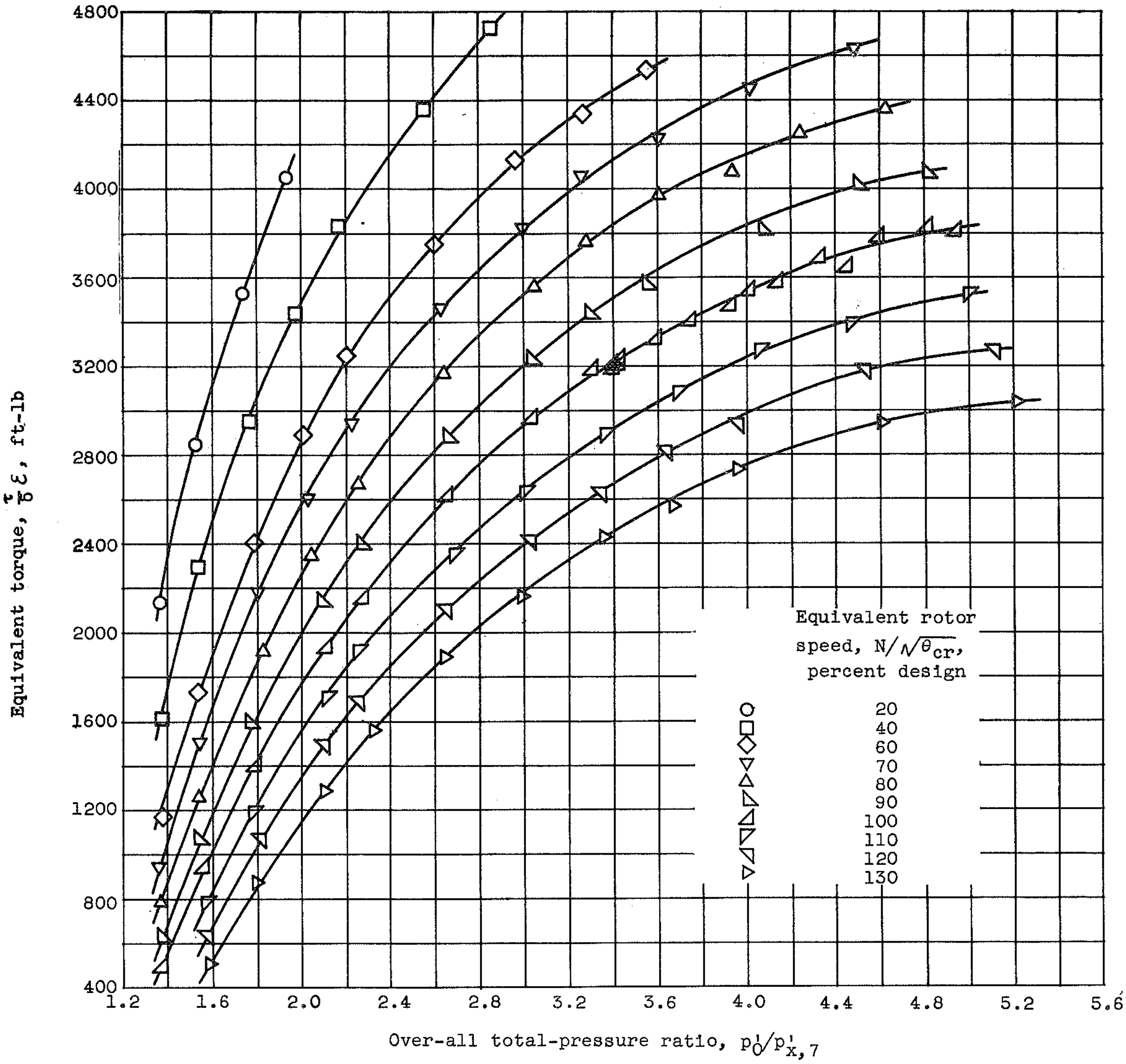


Figure 6. - Variation of equivalent torque with over-all total-pressure ratio for values of constant equivalent rotor speed.

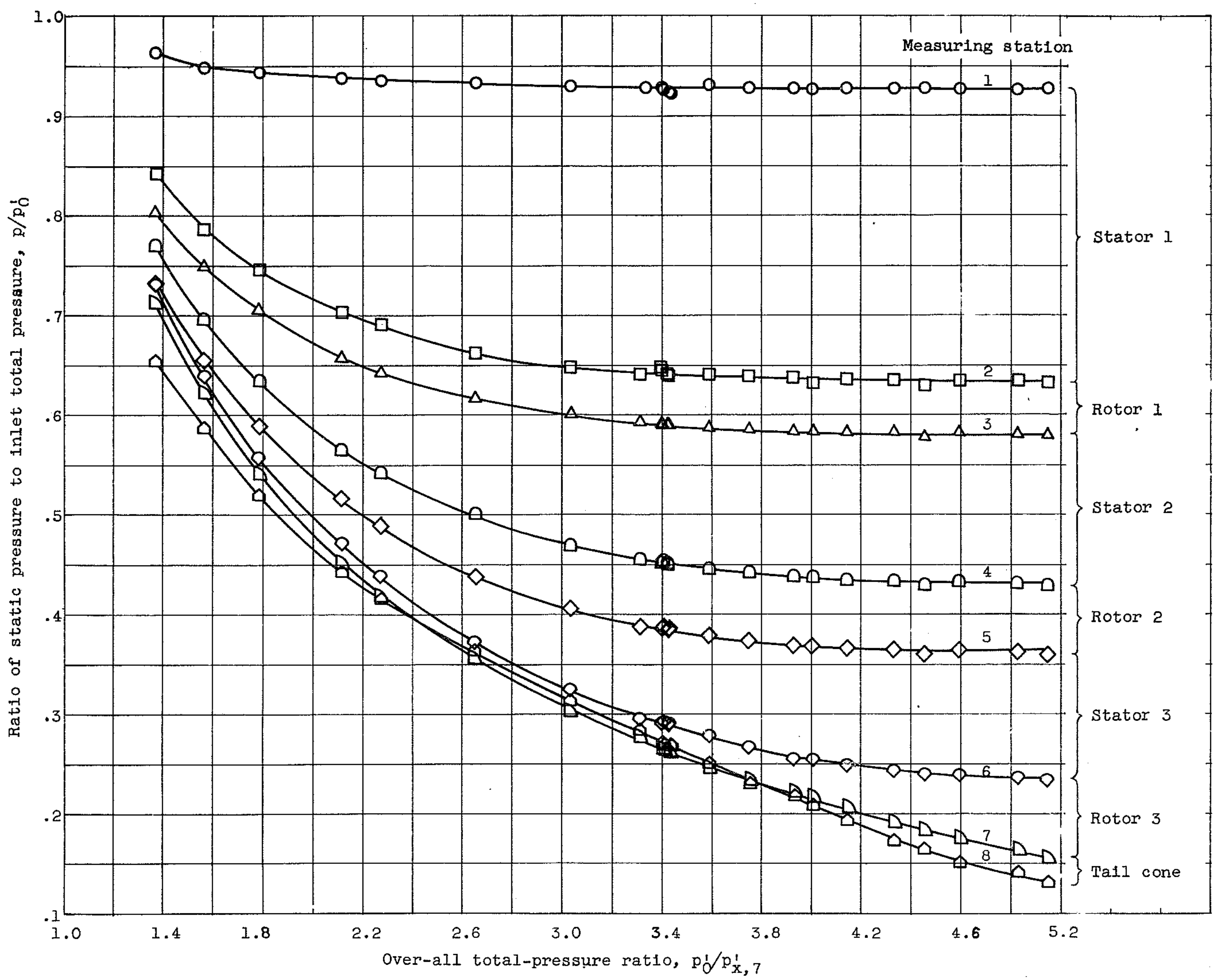


Figure 7. - Variation of ratio of static pressure at hub to inlet total pressure with over-all total-pressure ratio at different measuring stations for design equivalent speed.

COMPONENT PERFORMANCE INVESTIGATION OF J71 TYPE II TURBINES

III - OVER-ALL PERFORMANCE OF J71 TYPE IIA TURBINE

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Engines, Turbojet 3.1.3

Turbine Flow Theory and Experiment 3.7.1

Turbines - Axial Flow 3.7.1.1

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COMPONENT PERFORMANCE INVESTIGATION OF J71 TYPE II TURBINES
III - OVER-ALL PERFORMANCE OF J71 TYPE IIA TURBINE

Abstract

The J71 Type IIA turbine had a brake internal efficiency of 0.880 and passed the equivalent design weight flow at equivalent design speed and work. A comparison of the over-all performance of this turbine with that of the Type IIF turbine at this equivalent design operating point indicated that the use of curve-backed blades and the reduction of the blade throat areas downstream of the first stator in the IIA turbine resulted in a slight increase in efficiency and a 5-percent decrease in weight flow.